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Shin-Hsuan et al.

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(54) MINIATURIZED MULTI-LAYER COPLANAR WAVE GUIDE LOW PASS FILTER

(75) Inventors: **Tseng Shin-Hsuan**, Shindian (TW); **Lin Cheng-Kuo**, Jungli (TW); **Wang Yin-Ching**, Banchiau (TW); **Huang Fan-Hsiu**, Taipei (TW); **Chan Yi-Jen**, Jungli (TW)

(73) Assignee: **Cyntec Co., Ltd.**, Hsinchu (TW)

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(22) Filed: **Apr. 25, 2003**

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(51) **Int. Cl.**[7] **H01P 1/203**

(52) **U.S. Cl.** **333/204**; 333/161; 438/205; 438/622

(58) **Field of Search** 333/204, 157, 333/158, 161; 438/250, 251, 622, 624

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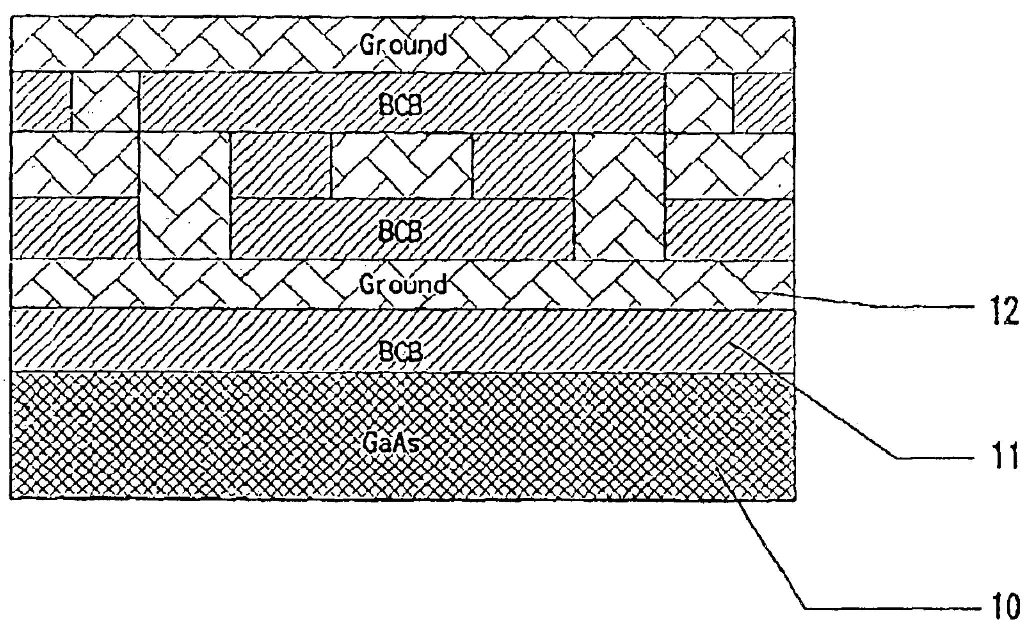
Primary Examiner—Timothy P. Callahan
Assistant Examiner—An T. Luu
(74) *Attorney, Agent, or Firm*—Troxell Law Office PLLC

(57) **ABSTRACT**

The present invention discloses a miniaturized multi-layer coplanar wave guide low pass filter including: a substrate; a first dielectric layer formed on and enclosing said substrate; a first metallic pattern layer formed on said first dielectric layer; a second dielectric layer formed on said first metallic pattern layer; wherein several via holes being formed on said second dielectric layer; a second metallic pattern layer formed on said second dielectric layer, wherein said via holes formed on said second dielectric layer are filled up with the metal thereof; a third dielectric layer formed on said second metallic pattern layer, wherein several via holes being formed on said third dielectric layer; and a third metallic pattern layer formed on said third dielectric layer, wherein said via holes formed on said third dielectric layer are filled with the metal thereof.

4 Claims, 9 Drawing Sheets



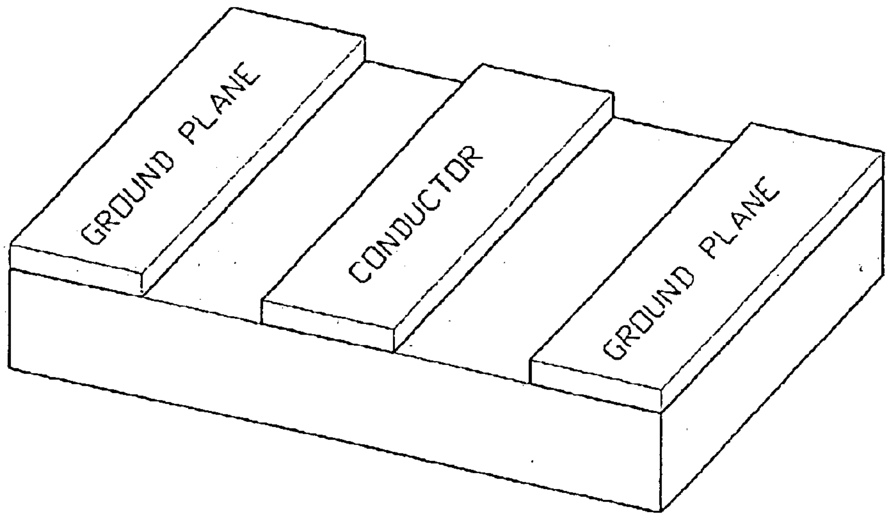


FIG. 1

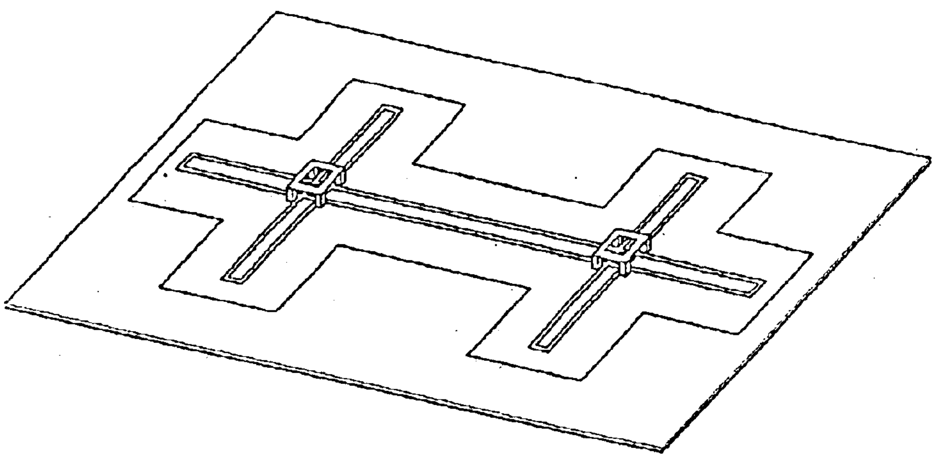


FIG. 2

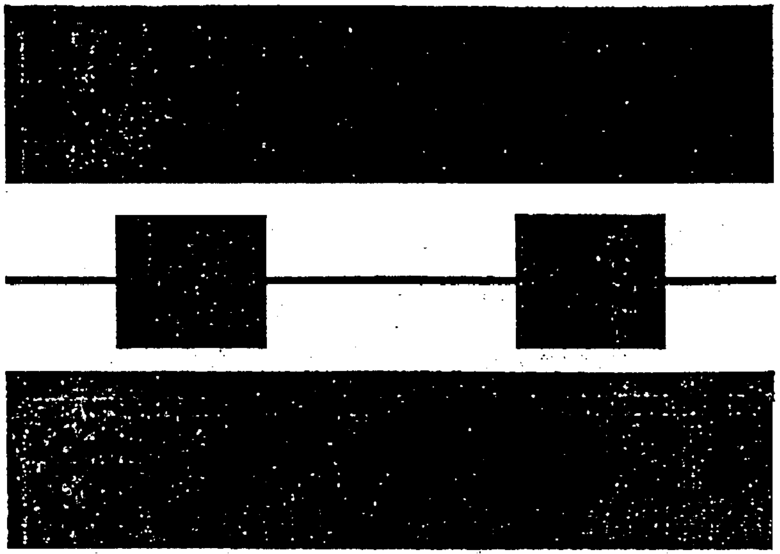


FIG. 3

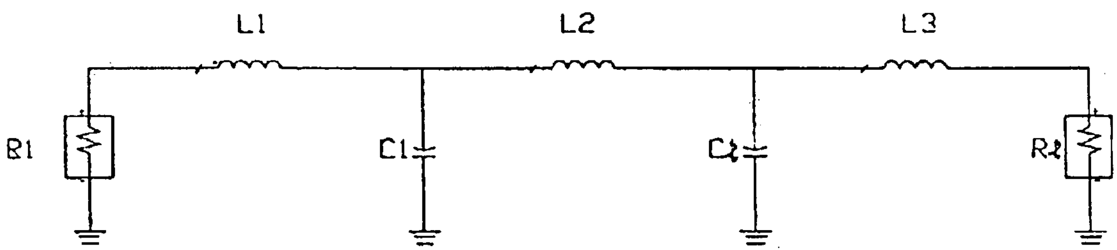


FIG. 4

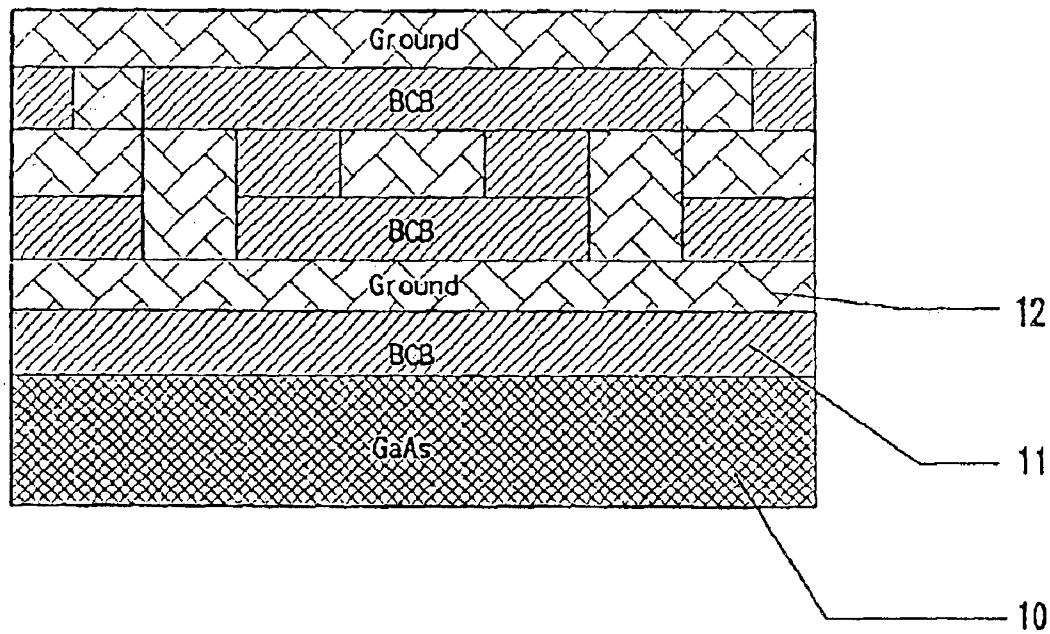


FIG. 5

FIG. 6A

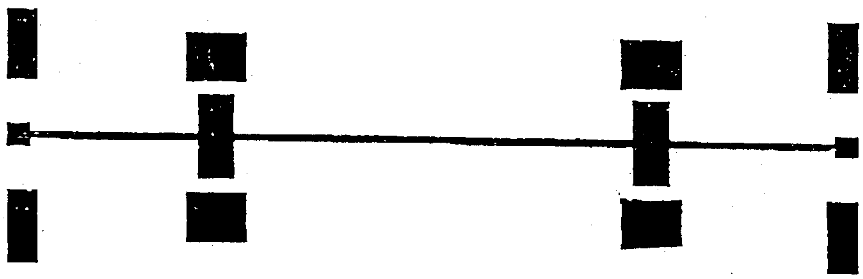


FIG. 6B

FIG. 6C

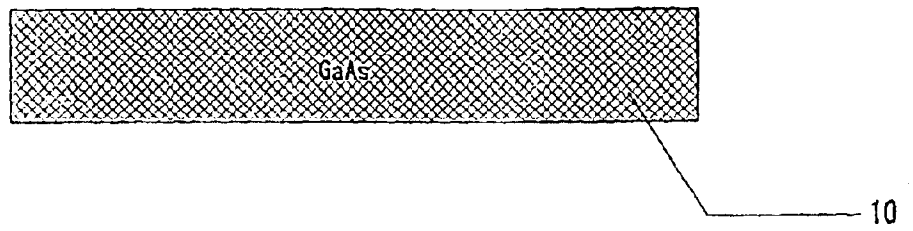


FIG. 7A

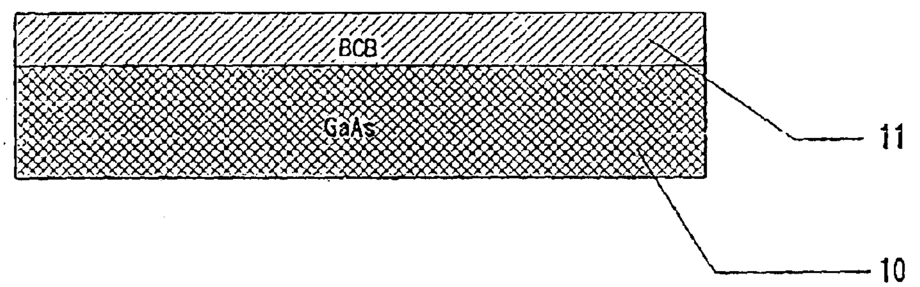


FIG. 7B

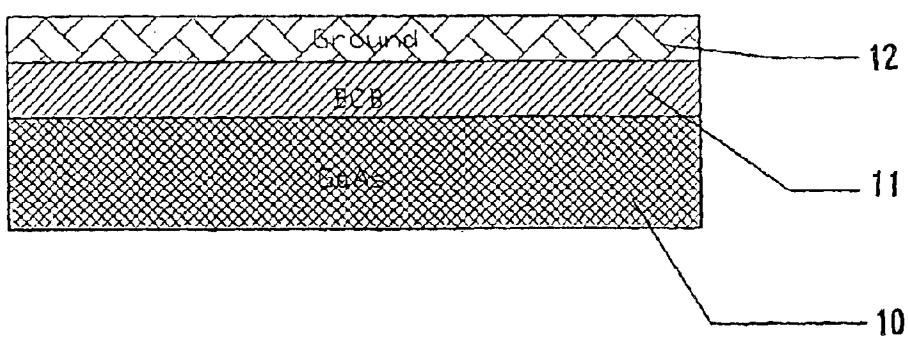


FIG. 7C

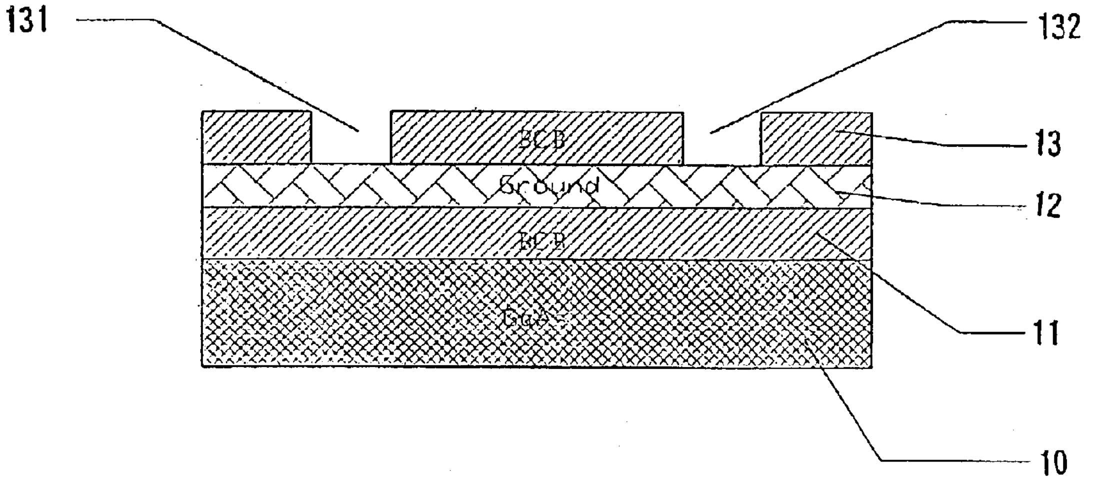

131
132
BCB
13
Ground
12
BCB
11
GaAs
10

FIG. 7D

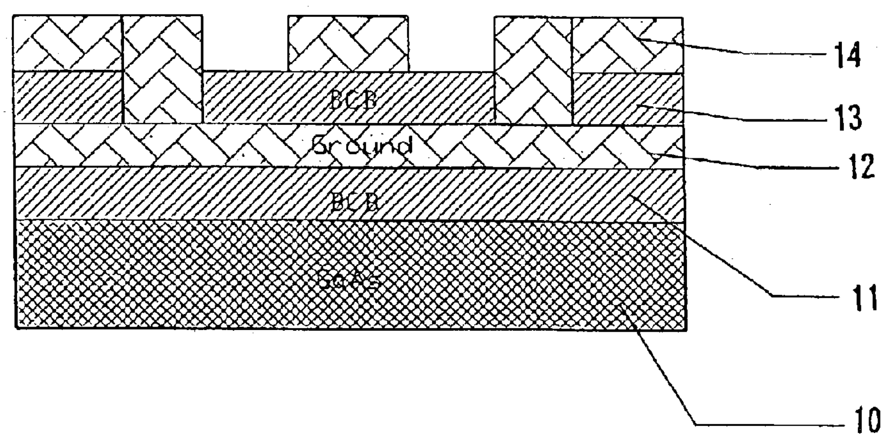

14
BCB
13
Ground
12
BCB
11
GaAs
10

FIG. 7E

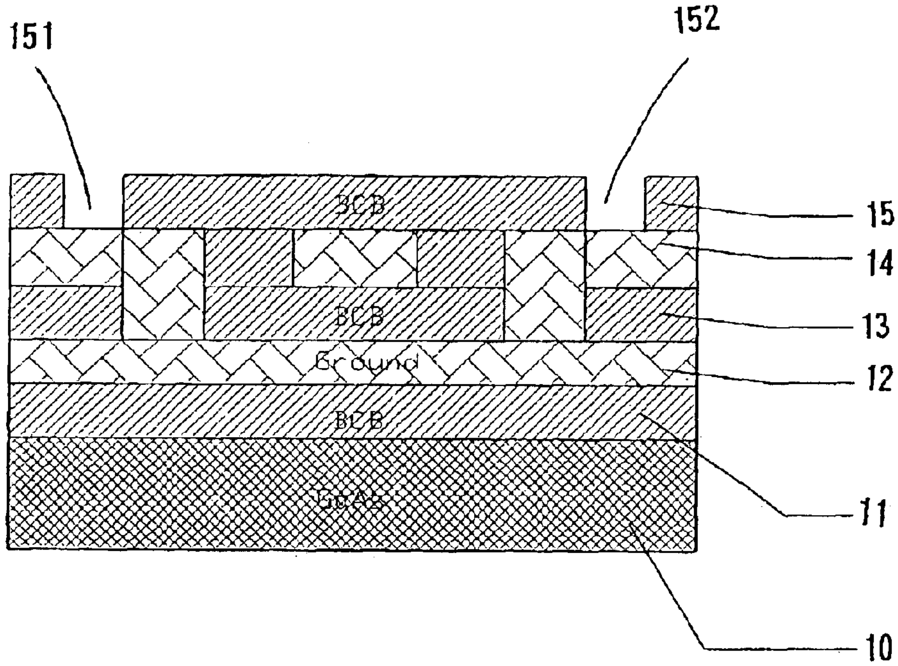

151
152
BCB
15
14
BCB
13
Ground
12
BCB
11
GaAs
10

FIG. 7F

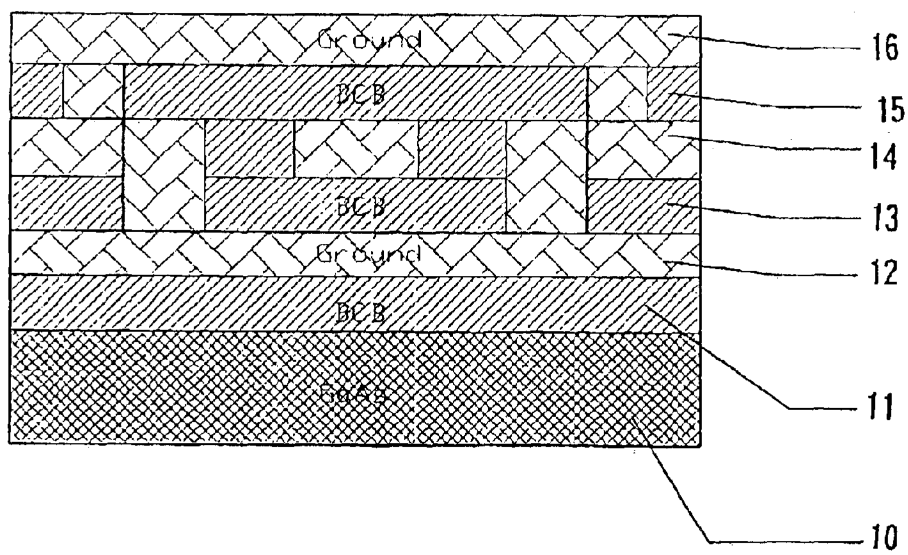

Ground
16
BCB
15
14
BCB
13
Ground
12
BCB
11
GaAs
10

FIG.7G

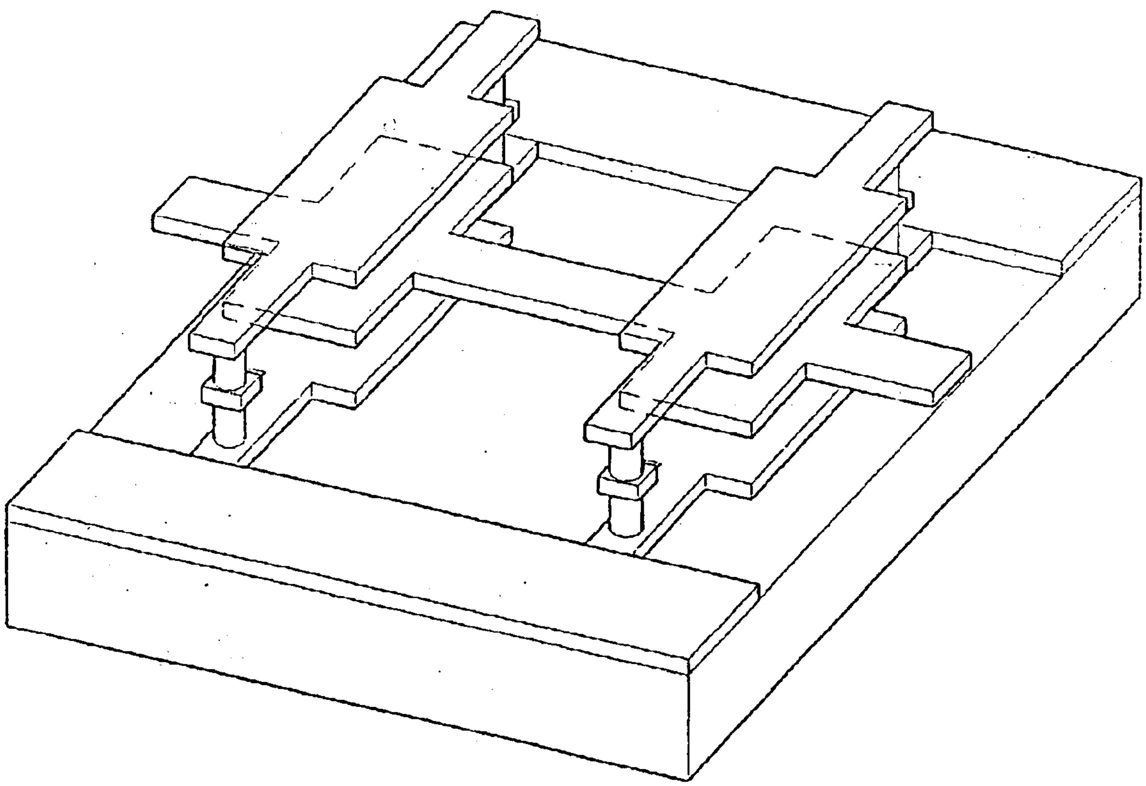


FIG. 8

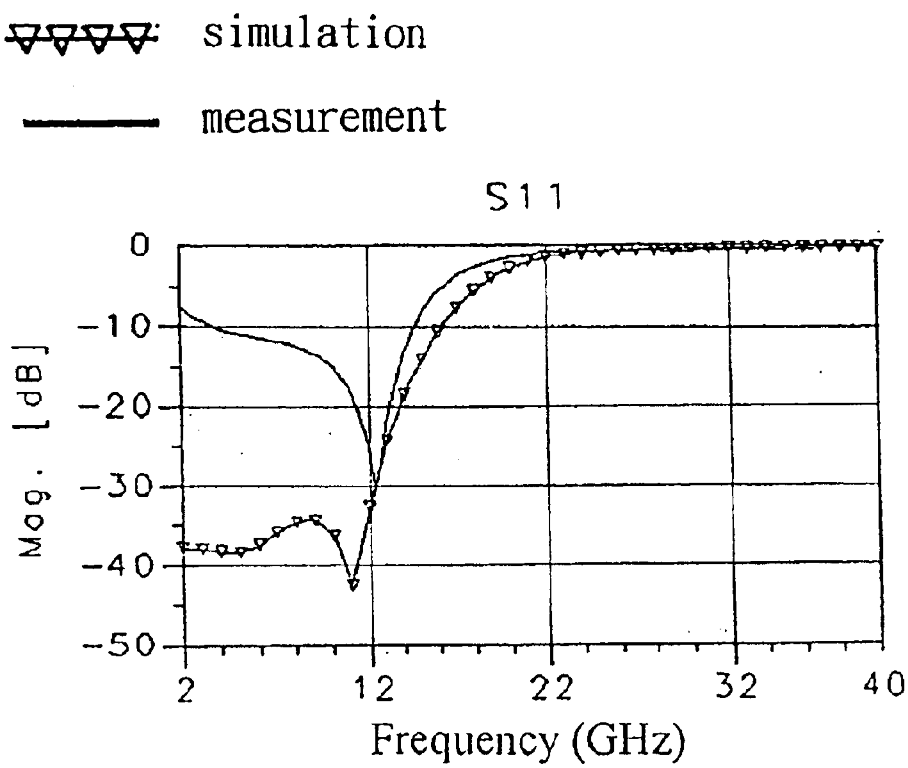

simulation
measurement
S11
0
-10
-20
-30
-40
-50
Mag. [dB]
2
12
22
32
40
Frequency (GHz)

FIG. 9

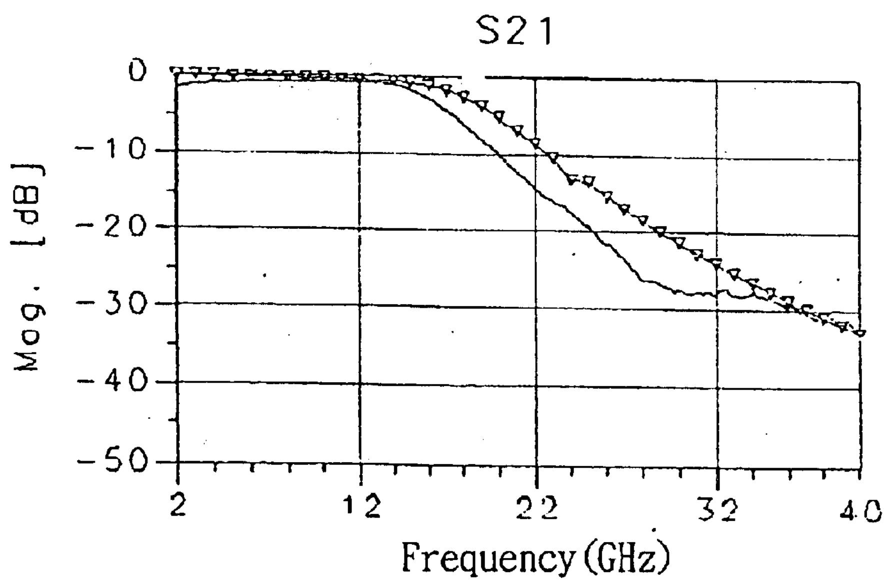

S21
0
-10
-20
-30
-40
-50
Mag. [dB]
2
12
22
32
40
Frequency (GHz)

FIG.10

MINIATURIZED MULTI-LAYER COPLANAR WAVE GUIDE LOW PASS FILTER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a miniaturized multi-layer coplanar wave guide low pass filter, and more particularly, to a miniaturized multi-layer coplanar wave guide low pass filter which is capable of enlarging the region of the characteristic impedance of a transmission line and miniaturizing the size of a filter by utilizing a multi-layer coplanar wave guide.

2. Description of the Prior Art

As it is well known, a filter is essentially composed of series inductors and parallel capacitors.

A low pass filter plays an important role on the microwave circuit, and is used to eliminate noises in a frequency change over circuit. However, the operation frequency in a new generation mobile communication system has been raised up to 30 GHz and above so as to cope with the trend of rapid development of the modern radio communication technology, and the design of transmission and distribution mode should be considered to operate the electromagnetic wave having the frequency 30 GHz and above.

For achieving the aforesaid object, the design of a well-known coplanar wave-guide structure which has been presented by Mr. C. P. Wen in 1969 is used. Its basic construction is shown in FIG. **1** in which the conductor and the grounding plate are made of a metal including gold, copper, etc. Meanwhile, the normal size of T.H.G.H is remained uncertain and is left it to the manufacture's decision, thereby having the merits of obtaining a simple coplanar structure with other active components, and omitting the processes of backside metallization and via hole forming so as to facilitate the fabrication process. Besides, the characteristic impedance is determined by the proportion of width between vacant slot and signal wire so that its electrical properties are less influenced by the thickness of the substrate. Moreover, as it is a real simple coplanar structure whose transmission line, signal wire, and ground wire is in the same plane so that cascading and paralleling among circuits can be easily performed by omitting formation of extra via holes which is necessary in a microstrip transmission line. The above mentioned via holes tend to bring about innegligible inductance effect at high frequency resulting in reducing efficiency of the circuit. Eliminating vertical via holes not only leads to reduction of circuit fabrication cost, but also enables to improve the selectivity of the circuit layout.

In bygone time, the two dimensional mode is usually employed when designing a coplanar wave guide low pass filter as shown in FIG. **2**, wherein the equalizing potential among metal parts is mainly performed by means of bonding or air bridging. However, it is found to be impracticable as the area occupied by these circuits is considerably large. Therefore, it is an urgent matter as to effectively minimizing the area occupied by a circuit when designing a low pass filter. Accordingly, the inventor of the present invention disclosed a two-dimensional coplanar wave guide low pass filter based on the principle of step type impedance as shown in FIG. **3**. It can be seen that such a two-dimensional coplanar wave guide low pass filter has a merit capable of saving process of bonding and forming air bridges among metal parts. Furthermore, for an equivalent circuit, a five order low pass filter was disclosed according to Butterworth model as shown in FIG. **4**.

In the meanwhile, it is found the area of this two-dimensional coplanar wave guide low pass filter is still unable to be reduced to a satisfactory extent which complies with the compactness of light, thin, short, and small that fulfils the current radio communication system's needs.

In addition, the conventional coplanar wave guide filter has a characteristic impedance in the range of 50~70Ω which is considered one of the disadvantages when it is to be in match with the network.

Aiming at the above-depicted defects, the present invention is to propose an innovative miniaturized multi-layer coplanar low pass filter after long time efforts made by the present inventor which is capable of eliminating the disadvantages inherent to the conventional products.

SUMMARY OF THE INVENTION

Accordingly, it is a first object of the present invention to provide a low pass filter which can greatly reduce the area occupied by the filter so as to fulfill the current radio communication system's needs of light, thin, short, and small structure.

It is a second object of the present invention that the provided low pass filter is a miniaturized multi-layer coplanar wave guide low pass filter whose metallic parts, substrate material, and dielectric material are all incorporated to greatly enlarge the region of its characteristic impedance.

It is a third object of the present invention to provide a miniaturized multi-layer coplanar low pass filter which can be fabricated by thin film fabrication technology therefore not only capable of achieving the product compactness but also greatly reducing the time and cost for production so as to strengthen the competitive ability in the market.

It is a fourth object of the present invention to provide a miniaturized multi-layer coplanar low pass filter whose applicable range of its characteristic impedance is greatly widened so as to facilitate this filter to match with the network.

BRIEF DESCRIPTION OF THE DRAWINGS

For fuller understanding of the nature and objects of the invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. **1** is a schematic view of a basic coplanar wave guide structure;

FIG. **2** is a schematic view of a coplanar wave guide low pas filter fabricated according to two-dimensional mode;

FIG. **3** is a schematic view of a two-dimensional coplanar wave guide low pass filter designed according to the principle of step type impedance;

FIG. **4** is an equivalent circuit for a five order low pass filter designed according to Butterworth Model;

FIG. **5** is a cross-sectional view of the miniaturized multi-layer coplanar wave guide low pass filter according to the present invention;

FIG. **6A~6C** are schematic views showing three different metallic pattern layers;

FIG. **7A~7G** are cross-sectional views illustrating fabrication steps of the present invention;

FIG. **8** is a three-dimensional view of the miniaturized multi-layer coplanar wave guide low pass filter according to the present invention;

FIG. **9** is a graph showing the deviation in return loss of the present invention between computer simulation and actual measurement; and

FIG. **10** is a graph showing the deviation in dielectric loss of the present invention between computer simulation and actual measurement.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The structure and shortcomings of the conventional two-dimensional coplanar wave guide low pass filter have already been illustrated above therefore will not be described herein again.

Referring to the equivalent circuit for a five order low pass filter according to the present invention shown in FIG. **4**, and its structure shown in FIG. **5**, the equivalent circuit includes three inductances L**1**, L**2**, and L**3** connected in series, and two capacitance C**1**, C**2** connected in parallel. The structure thereof shown in FIG. **5** includes a substrate **10** preferably made of Al_2O_3 with Σr=9.8, and a thickness of preferably 200~350 μm; a first dielectric layer **11** enclosed over the substrate **10**, the dielectric layer **11** is preferably made of Benzocyclobutene having a low dielectric constance (K≈2.6), a low tangential loss (tan θ≈0.002), and a preferable thickness of 2~3 μm, in addition to the property of low dielectric constant and low tangential loss, it should be of good adhesiveness with the metallic materials and the substrate of negative photoresistivity, suitable for drilling via holes and forming into multi-layer structure, a first metallic pattern layer **12** (see FIG. **6**A) formed on the first dielectric layer **11**, preferably made of gold with a thickness less than 1.5 μm; then a second dielectric layer **13**, a second metallic pattern layer **14**, a third dielectric layer **15**, and a third metallic pattern layer **16** are formed on the first metallic pattern layer **12** in order, wherein the second and third dielectric layers **13**, **15** are made of similar material with, and have the equal thickness to the first one **11**, while the second and third metallic pattern layers **14**, **16** are made of the similar material with, and have the equal thickness to the first one **12**, the only difference between the two pattern layers **14**, **16** from the first metallic pattern layer **12** are shown in FIGS. **6**B and **6**C.

The fabrication steps of the present invention are illustrated in FIGS. **7**A to **7**G. The steps comprise:

(a) providing a substrate **10** made of the material described above, it may be GaAs, Al_2O_3, FR_4 etc., preferably Al_2O_3;

(b) enclosing a first dielectric layer **11** over the substrate **10**, the material to be used for the layer **11** is preferably Benocycolobutene;

(c) forming a first metallic pattern **12** on the first dielectric layer **11**, the material to be used for the layer **12** is preferably gold with a pattern shown in FIG. **6**A;

(d) enclosing a second electric layer **13** over the first metallic pattern layer **12**, material to be used for the layer **13** is preferably benzocyclobutene, and forming via holes **131**, **132** using a developer after exposure;

(e) forming a second metallic pattern layer **14** on the second dielectric layer **13**, and filling up the via holes **131**, **132** which have been previously formed on the second dielectric layer **13**;

(f) forming a third dielectric layer **15** on the second metallic pattern layer **14** using the similar material as that of the first and second dielectric layers **11**, **13**, and forming via holes **151**, **152** using a developer after exposure; and

(g) forming a third metallic pattern layer **16** on the third dielectric layer **15**, and filling up the via holes **151**, **152** which have been previously formed on the third dielectric layer **15**.

The resultant three dimensional structure of the miniaturized multi-layer coplanar wave guide low pass filter of the present invention formed by above described steps is shown in FIG. **8**.

It can be seen from the above description that the miniaturized multi-layer coplanar wave guide low pass filter has some noteworthy features, i.e.:

1. A low dielectric constant (Σr=2.6), a low tangential loss (tan δ=0.002) can be realized by using benzocyclobutene as the dielectric material. Moreover, using gold as the metal layer results in a good conductivity (δ=4.117) and an excellent ductility. The above two factors combined to cause the filter of the present invention to have a good conducting and small size whose overall thickness is as thin as below 15 μm.
2. Application of multi-layer coplanar wave guide results in enlarging the region of the characteristic impedance of the transmission line and reducing the size of the filter as well. The characteristic impedance is in the range 3 Ω~103Ω.
3. The results of simulated and actually measured return loss and dielectric loss shown respectively by the graphs of FIG. **9** and FIG. **10** prove the fact that the circuit characteristic of the filter according to the present invention attains the expected effect practically suitable for industrial application.

A variety of modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the present invention may be practiced otherwise than as specially described hereinabove.

What is claimed is:

1. A miniaturized multi-layer coplanar wave guide low pass filter comprising:

a substrate;

a first dielectric layer formed on and enclosing said substrate;

a first metallic pattern layer formed on said first dielectric layer;

a second dielectric layer formed on said first metallic pattern layer, wherein several via holes are formed on said second dielectric layer;

a second metallic pattern layer formed on said second dielectric layer, wherein said via holes formed on said second dielectric layer are filled up with the metal of the second metallic pattern layer;

a third dielectric layer formed on said second metallic pattern, wherein several via holes are formed on said third dielectric layer; and

a third metallic pattern layer formed on said third dielectric layer, wherein said via holes formed on said third dielectric layer are filled up with the metal of the third metallic pattern layer, the first dielectric layer, the second dielectric layer and the third dielectric layer having equal thicknesses.

2. The low pass filter as in claim **1**, wherein said substrate is made of a material selected from a group consisting of Al_2O_3 and FR_4.

3. The low pass filter as in claim **1**, wherein said first, second, and third dielectric layers are formed with benzocyclobutene.

4. The low pass filter as in claim **1**, wherein said first, second, and third metallic pattern layers are formed with gold.

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